Review of Surface Runoff in Flood Risk Areas of Makassar Citythrough Modified Rational Methods

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***Abstract*—The purpose of this research was to determine the surface runoff and the puddle in the of flood risk area in Manggala village. Modified Rational Method had been applied to determine runoff discharge. It is a recent transformation of the Rational Method that can be used to not only compute peak runoff rates, but also to estimate runoff volumes and hydrographs. While, flood risk areas were based on the map from National Disaster Management (BPBD Kota Makassar, 2014). Rainfall data of Manggala village wascollected from 2009 to 2018 from three stations, they areBiringRomang, Panakukkang, and TamangapaKassi. Therefore, a Thiessen method had been applied to determine the rainfall area.Research results shown that runoff discharge for return period 5 years was3.16 m3/s, with height around 0,50 to 2,00 m.**

Keywords:*Runoff discharge, Modified Rational Method, puddle*

I. Introduction

Flooding in urban areas seems to be more frequent. Several factors, not just climate change and rainfall patterns. But urban development, changes in land cover and development in areas at risk of flooding[1]. This will be exacerbated by the development of population and city planning that is not well planned will have the potential for more widespread inundation areas[1][2].

Changes in land use and land cover are a common consequence of urban expansion that affects runoff discharge by modifying how rainfall flows on the surface of the land toward water bodies[2][3].

Management of inundation in vulnerable risk areas is a priority for Makassar city [4]. One of the hilly areas of Makassar city facing the problem of flood risk is Bangkalaarea (BPBD, 2014). Inundation height reaches as high as 100 - 150 cm due to rainfall and the expansion of residential areas that did not follow the map of flood prone to Makassar.

In planning in the field of water resources, it is often necessary to have a realistic data plan flood discharge. Plan floods with certain return periods can be calculated and flood discharge data or rain data[5]. The Modified Rational Method is a recent transformation of the Rational Method that can be used to not only compute peak runoff rates, but also to estimate runoff volumes and hydrographs[6].It is sufficiently accurate to estimate runoff over areas with impervious land cover or urban areas[6][7].

This study uses a modified rational method in expansive urban to see surface runoff where runoff of rainfall is distingushed in its routing effect. So the C coefisient consist of two parts, namely the volumetric runoff coefisient and the routing coefisent of land toward water bodies[8].

II. Research Method

A. Research Location

This research took place in Bangkala Village, Manggala District, Makassar City,

Figure1.Research Location kel. Bangkala

B. Data Collection

Primary data used were direct measurements using, GPS, at the study site.

Topographic map data, Makassar city flood map, Makassar city flood elevation map (BPBD, 2014), rainfall data from BMKG Wil. IV Makassar and the PSDA Service.

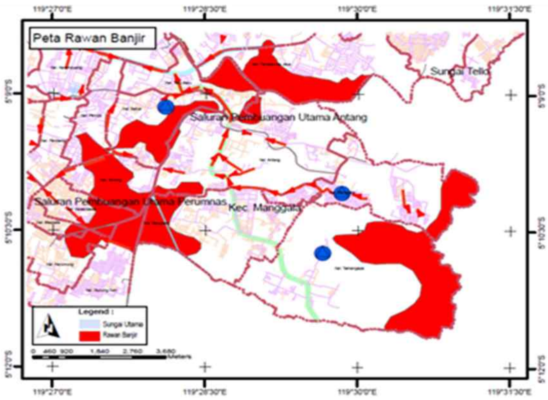

Figure 2.Map of risk of flood-prone Bangkala

C. Technique of Analysis Data

1. Analysis of secondary data

The data obtained was then processed with software (Surfer, Google Earth, and AutoCad so as to get the contours like Figure 3.

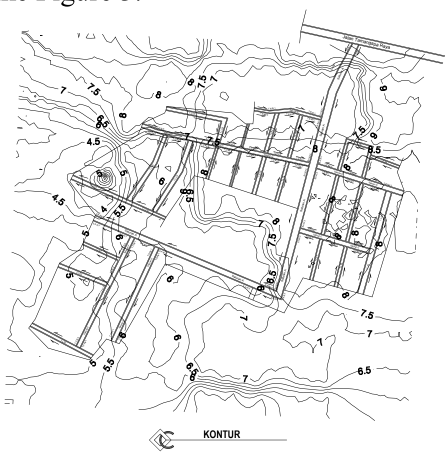

Figure 3. Contour and impervious area

2. Analysis of primary data

Existing data obtained in primary data was then processed by the modified rational method. The results of runoff discharge was used to determine the high inundation in the Makassar flood risk area.

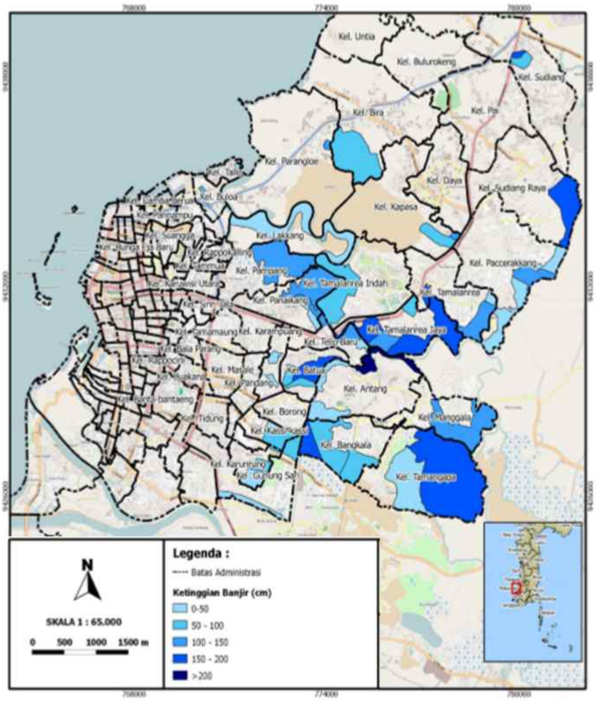

Figure 4. Map of Makassar city flood elevation

D. Flow Chart

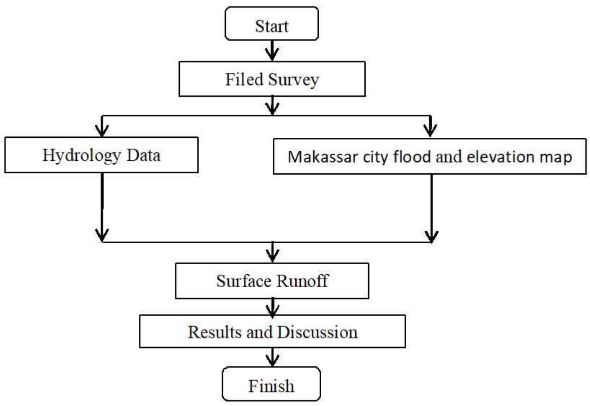

Figure 5. Conceptual Framework

From field studies, depicted area (area of the watershed) the risk of being prone to flooding is 142.15 ha (according to figure 1) with inundation height of 1.0 to 1.5 m, (figures 2 and 4).

There are 3 point rainfall data covering the drainage area of the Bangkala village. The arithmetic method and the Thiessen Method are used to calculate the average regional rainfall presented in Tables 1 and 2 and then a rainfall frequency analysis is performed to determine the planned rainfall.

There are 4 frequency distribution tests to determine the rain return plan, namely the Gumbel Distribution, Normal, Normal Log and Type Person Log III, as presented in table 3.

From Figure 3, Length of the main water linewater and are determined by GPS tracking in the field as depicted in figure 3. From the figure, the area of impervious cover and pervious cover is calculated based on field conditions.

Runoff percentage was determined by equations 3 and 4. The impervious percentage representing the degree of urban development of the depicted was calculated by equation 5.

Peak discharge with the modified rational method is calculated using equation 1. By entering the conversion factor 0.002778 and dimension routing coefficient 1.3 [4]

III. Results and Discussion

A. Calculation of Rainfall

Analysis of rainfall requires rainfall data in a certain period of time. In the analysis of the more data series used, the smaller the error in the analysis. Rainfall analysis also requires a comparison station that is useful in consistency testing. Annual maximum rainfall data is obtained from data from the Public Works department in the field of PSDA and the Makassar Meteorology, Climatology and Geophysics Agency IV for the period 2009 - 2018, including:

1. BiringRomang Station
2. Ujung Pandang Station
3. TamangapaKassi Station

Then processed to get the maximum average rainfall.

Table 1. Maximum Rainfall Data (mm / day)

No.	Years	Arithmatic Method			Average
		Biring Romang	Panakukkang	Tamangapa Kassi.	
1	2009	146	113	90	116
2	2010	109	91	80	93
3	2011	180	217	120	172
4	2012	97	115	118	110
5	2013	155	193	98	149
6	2014	138	135	120	131
7	2015	136	139	142	139
8	2016	167	142	90	133
9	2017	156	178	145	160
10	2018	135	145	152	144

The aerial rainfall in the Bangkala catchment area is calculated by the following Thiessen Method equation:

$$R = \frac{A_1.\ R_1 + A_2.\ R_2 + ...A_n.\ R_n}{A_1 + A_2 + ...A_n}$$

Where :

R = Average rainfall (mm)

$A_1, A_2,... A_n$ = The area of the Thiessen area represents the point of rainfall

$R_1, R_2,... R_n$ = The amount of rainfall in each station (mm)

Based on the formula above, the average regional rainfall is obtained as follows:

Table 2. Maximum Daily Rainfall

No.	Years	Thiessen Method			Total aerial rainfall
		Biring Romang	Panukkang	Tamangapa Kassi	
		0.122	0.161	0.717	
1	2009	17.82	18.19	64.53	100.54
2	2010	13.31	14.65	57.36	85.31
3	2011	21.97	34.92	86.04	142.94
4	2012	11.84	18.51	84.60	114.95
5	2013	18.92	31.06	70.26	120.25
6	2014	16.85	21.73	86.04	124.61
7	2015	16.60	22.37	101.81	140.78
8	2016	20.39	22.85	64.53	107.77
9	2017	19.04	28.65	103.96	151.65
10	2018	16.48	23.34	108.98	148.80

In statistics there are several types of distribution, including Normal, Gumbel, Normal Log, Pearson Type III Log. For this reason, the type of distribution in accordance with the distribution of debit data in the study area is reviewed. This can be searched by analytical and plotting data.

Here are the results for the distribution selection by means of analysis:

Table 3. Distribution Test Results

No.	Distributions	Requirements	Results	Remaks
1	Gumbel	Cv = 1,14	Cv = 0.18	No
		Ck = 5,4	Ck = 3.09	No
2	Normal	Cs = 0	Cs = -0.32"	No
		Ck = 3	Ck = 3.63	No
3	Log Normal	Cs = 0,137	Cs = -0.61	No
		Ck = 3,033	Ck = 3.63	No
4	Log Person III	if all requirements are not fulfilled	Cs = -0.61	yes
			Ck = 3.63	yes

From the calculation that has been done above with the above conditions, the closest distribution is chosen, namely the Log Person Type III distribution. Next, calculate the rainfall plan using the Log Person Type III method.

Table 4. Results of Rain Calculation for the Pearson Log Method Type III

No.	Years	Xi	LOG Xi	(LOG Xi-LOG Xrt)^2	(LOG Xi -LOG Xrt)^3
1	2009	101	2.002	0.00699	-0.00058
2	2010	85	1.931	0.02400	-0.00372
3	2011	143	2.155	0.00479	0.00033
4	2012	115	2.061	0.00064	-0.00002
5	2013	120	2.080	0.00003	0.00000
6	2014	125	2.096	0.00009	0.00000
7	2015	141	2.149	0.00392	0.00025
8	2016	108	2.032	0.00285	-0.00015
9	2017	152	2.181	0.00901	0.00086
10	2018	149	2.173	0.00751	0.00065
Amonut		1238	21	0.05985	-0.00238
N	10				
Log Xrt	2.085913				
S	0.081550				
Cs	-0.611				

Furthermore, the probability distribution test is intended to determine whether the selected probability distribution equation can represent the statistical distribution of the analyzed data sample.

- **Smirnov-Kolmogorov Test**

The calculation of the distribution match test with Smirnov - Kolmogorov for the Normal Log Method in the study area can be seen in Table 4.10.

Table 5. Kolmogorov - Smirnov Test

No.	Xi	the empirical distribution function (Pe)	Theoritical distribution probability(Pt)	Test Statistic D (Pe-Pt)	Xt
1	85	9.09	4.23	4.86	-1.151161207
2	101	18.18	19.26	1.07	-0.499143677
3	108	27.27	29.86	2.59	-0.189530609
4	115	36.36	41.12	4.76	0.118109662
5	120	45.45	49.24	3.79	0.344785264
6	125	54.55	55.56	1.02	0.531651396
7	141	63.64	74.53	10.89	1.224169418
8	143	72.73	76.48	3.75	1.316261441
9	149	81.82	81.17	0.65	1.567292017
10	152	90.91	83.14	7.77	1.689566295
Average	124				
N	10				
Significancy	5%				
D critical	41				
D maximum	10.89				

From the calculation of the D value, Table 5, shows the Dmax value = 10.89, the data at rank n = 10. By using a 5% degree of confidence, the Do = 41 is obtained. Because the Dmax value is smaller than the critical Do value (10.89 <41), then the distribution equation obtained can be accepted.

- **Chi-Square Test**

The chi-square test is intended to determine whether the distribution equation that has been selected can represent the statistical distribution of the sample of the analyzed data.

Table 6.Chi-Square Test Calculation Results

Boundary Value of Interval class	Ei	Oi	$(Ei - Oi)^2$	$(Ei - Oi)^2/Ei$
1,8895 < X < 1,9725	2.5	1	2.25	0.9
1,9725 < X < 2,0555	2.5	2	0.25	0.1
2,0555 < X < 2,1385	2.5	3	0.25	0.1
2,1385 < X < 2,2215	2.5	4	2.25	0.9
Amount	**10**	**10**	**5**	**2**

Based on the table for degrees of freedom 1 and α = 5% obtained a critical value (χ2 critical) = 3.841 So, it can be concluded: χ2 hit <χ2 critical (2 <3,841), then the distribution is accepted

The design rainfall intensity, i, for use in the Rational Method equation is the intensity of a constant intensity design storm with return period equal to a specified value for the purpose of the peak runoff rate being calculated, and duration equal to the time of concentration of the watershed.

Rainfall Intensity Analysis using the Mononobe method is rainfall per unit time, hasilnyadisajikan pada gambar 4.

$$I = \frac{R_2}{24}\left(\frac{24}{t}\right)^{2/3}$$

Where :

R = local design rainfall (mm)
t = duration of rainfall (hour)
I =rainfall intensity (mm/hour)

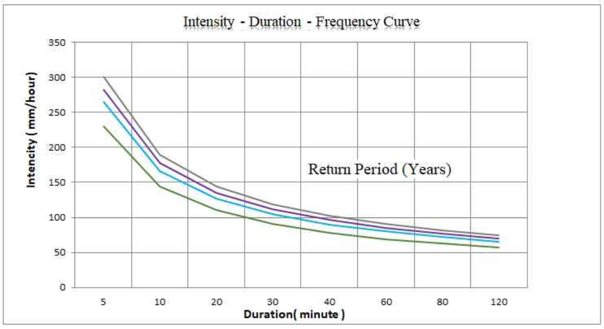

Figure 6. Rainfall Intensity Graph

B. Flood Discharge Analysis

There are several flood discharge analysis methods that can be used based on the characteristics of the watershed and the distribution of rain. But in this research for the analysis of flood discharge plans the modified Rational method is used below:

$$Q_p = 0{,}00278\ x\ 1{,}30\ x\ C_v\ x\ i\ x\ A_i \qquad (1)$$

Where :

Qp = Runoff discharge (m3/sec)
Cv = Volumetric coefficient of runoff
i = The intensity of rainfall (mm/hr)
A = Impervious Area of drainage (ha)
Cg = search coefficient (1 – 2)
0,00278 = conversion factor

$$C_v = \frac{P}{P_I} \qquad (2)$$

PR = 0,829 PIMP + 25,0 SOIL + 0,078 UCWI
[PR > 0,4 PIMP] (3)
PR = 0,4 PIMP [PR ≤ 0,4 PIMP] .eq.4

$$P_I = \frac{A_1}{A}\ x\ 100 \qquad \text{.....eq.5}$$

A_1 : Waterproof area (housing) (km^2)
A : Catchment area (km^2)
SOIL : Urban soil condition index (0,15-0,50)
UCWI : Urban land wetness index (30 – 300)

Many empirical equations are available for calculating watershed time of concentration. In this research, three that in use to calculating watershed time of concentration, The Manning Kinematic equation for overland sheet flow, The NRCS method for shallow concentrated flow, and finally, the Manning equation for channel flow.

$$t_c = \frac{5{,}48\, x\, (n\ )^{0{,}8}}{P^{0{,}5}\, x\, S^{0{,}4}} \ldots\text{..eq.6}$$

Tc : time of concentration (hour)

L : Length of flow path (km)

n : Manning roughness coefficient

S: the ground slope (m/m).

P : the 2 year, 24 hour rainfall depth (mm)

Table 7.Surface Runoff and high of Paddle.

Name of Area	Surface Runoff							
	L_2	Ai	Cv	PR	tc	I_{5th}	Qp	h
	(m)	*ha*			*(minute)*	*(mm/hr)*	*(m^3/sec)*	m
Bangkala	1191.02	54.40	0.79	30.22	46.14	20.34	3.16	0,5 - 2,5

Length of flow path , L, 119,02 m, is determined by contour of flow direction (figure 1 and 3). While, area of Waterproof (Houses, road) is 54,40 ha from total area of the watershed 142,15 ha (figure 1).

From equation 2, the value of Cv is 0.79. While the PR value is 30.22 greater than 0.4 PIMP from equation 3 with the travel time for overland sheet flow is 28,38 minute and peak discharge is 3,16 m3/sec,runoff volumes about 11.418,14 m3.

IV. Conclusion

The results of the overflow discharge assessment of the Manggala urban area with a modified rational method for a 5 year return period were 3,16 m3 / sec with a pool height of 0.50 - 2.00 m. This high inundation is higher than the map of the Makassar city flood risk area of 1.00 - 1.50 m, with a rainfall of 23.31 mm / hour.

Thank-you note

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